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ROYAL AEROSPACE ESTABLISHMENT

AIRFIELD LIGHTING - FUTURE TRENDS

by

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SUMMARY

This Memorandum takes a critical look at approach and runway lighting for fixed wing precision approaches. The importance of equipment maintenance is emphasised.

The Memorandum also considers the evolving requirements for visual aids to support helicopter operations and to enhance surface movement, guidance and control.

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1 INTRODUCTION

Airfield lighting is an essential part of the aviation business. Like the aircraft that they support, airfield lighting systems have over the years increased in size and sophistication and the financial and engineering investment in the equipment is a significant factor in the cost of an airfield. It is inconceivable even with a further expansion of the use of avionics that the need for visual signalling will ever by eliminated. However, the time is opportune to review the efficiency of present systems and predict possible future trends.

This Memorandum takes a critical look at approach and runway lighting for fixed wing precision approaches including maintenance standards and considers the needs for visual aids to support helicopter operations. The possible applications of new technologies to enhance surface movement, guidance and control systems is also reviewed.

2 REDUCED LIGHTING FOR PRECISION APPROACHES

The International Civil Aviation Organisation (ICAO) publishes standards for airfield lighting related to approach Categories 1, 2 and 3. Over the last 25 years ICAO has achieved a level of international agreement on these lighting patterns that is essential for the safe and regular operation of aircraft. In the military field standards similar to ICAO Category 1 generally apply. Fig 1 shows a typical lighting pattern for Category 1 operations, whilst Fig 2 illustrates the augmented patterns specified for Category 2 and 3 operations. In Table 1 the number of lights used in these patterns is shown for a 3000 metre (10000 ft) runway.

Table 1

Number of lights used

Lighting system	Category 1	Category 2	Category 3
Approach	120	120	120
Supplementary approach	-	108	108
Threshold/end	26	26	26
Runway edge	210	210	210
Runway centreline	-	105	210
Touchdown zone	-	120	120
Total	356	689	794

The large increase in the number of lighting units specified as operations move from the Category 1 to Category 2 regime is significant. A review of the research and development that produced these supplementary patterns suggests that the driving forces that resulted in the patterns as we have them today were:

(a) The need for a means of making a visual check of the accuracy of lateral delivery for coupled approaches on the ILS for decision heights less than 200 ft, due to the poor delivery accuracy of early ILS systems.

(b) The need for textural cues during the flare manoeuvre at night.

(c) The need for steering cues during the roll-out and for take-off.

Research at the RAE and in-service operational data has shown that for modern aircraft using recently designed airfield lighting these requirements can be relaxed. Specifically because modern systems deliver the aircraft more accurately there is no requirement to indicate offset distance which was the original purpose of the red approach barettes (although they also give an indication of the imminent approach to the threshold). Although in Category 2 conditions runway centreline lighting only comes in the 'nice to have' category, it is essential for RVRs below 300 metres (1000 ft) but as flight experience shows a 30 metre (100 ft) spacing is sufficient.

In addition, the magnitude and extent of the touchdown lighting must be re-examined. Again, due to the improved approach performance achieved by modern avionics it is difficult to justify the present length of the touchdown zone lighting pattern. A 1/3 reduction in length seems supportable and recent trials have shown that the barettes can be reduced in extent from 4 to 2 lights per barette. It is important to note that the threshold lighting must fully meet the intensity specifications.

Bearing in mind all the above-mentioned considerations and taking account of our recent research it seems feasible to propose that ICAO and military agencies review the specifications for Category 2 and 3 lighting to evaluate the premise that the more austere supplementary lighting shown in Fig 3 and documented in Table 2 is a sufficient minimum standard for safe and regular operations.

Table 2

Lighting system	Category 1	Category 2	Category 3
Approach	120	120	120
Supplementary approach	-	-	32
Threshold/end	26	26	26
Runway edge	210	210	210
Runway centreline	-	-	105
Touchdown zone	-	40	40
Totals	356	396	533

When considering this proposal, two inter-related points are relevent:

(a) The estimated full installation costs for these lighting options is as shown in Table 3.

Table 3

ICAO Category 1 to ICAO Category 2/3	£550000	($1000000)
ICAO Category 1 to proposed Category 2	£125000	($210000)
ICAO Category 1 to proposed Category 3	£350000	($600000)

Thus the proposed austere conversion for Category 1 to Category 3 lighting shows a 40% cost saving and the proposed austere conversion from Category 1 to Category 2 shows nearly an 80% cost saving.

(b) When considering costs it is important to note that many runways are only equipped to Category 1 standards. There is a strong possiblility that when MLS is deployed, many airport authorities will be under commercial pressure to provide Category 2 and Category 3 facilities. Anything that reduces costs must therefore be considered. Category 3 operations require very short lengths of approach lighting, but generally the full pattern will be provided to suppal Category 1 and 2 conditions.

3 MLS OPERATIONS

When future MLS operations are discussed the subject of possible modifications to approach and runway lighting is often raised.

MLS offers the possibility of offset initial approach paths and a range of selectable glideslope angles. In the context of lighting for *precision* approach runways it must be remembered that this lighting is designed and installed for use with instrument approach procedures. It is therefore only *designed* to support operations in the final stage of the approach, which for various reasons (auto-pilot performance and obstacle surfaces being the main ones) will always require an approach that is aligned with the runway centreline. Thus for precision approaches the azimuth characteristics of the lighting will not change. However, if the use of MLS results in standard visual procedures that turn the aircraft on to the final approach at shorter ranges than are currently used, then there is likely to be a shift of emphasis towards the use of omni-directional (strobe) approach lighting to provide the essential information as to the location of the extended centreline. In the vertical plane, because of the steeper glideslope angles which will be feasible it will be necessary to increase the vertical beamspread or change the setting angles of the approach and runway lighting to provide adequate cues for approach angles greater than 3°. If only one approach angle is used at a particular runway, then existing equipment with suitable setting angles will probably suffice, but if multiple glidepaths are envisaged an increase in beamspread becomes inevitable.

As an example, Fig 4 shows for an 800 metre RVR the predicted performance in terms of initial contact and the height at which a 150 metre visual segment will be established (a) for lighting currently specified for 3° approaches and (b) for lighting with increased vertical beamspread. In order to preserve performance for various glideslope angles in terms of substantially maintaining the same *range* for contact height and usable 150 metre segment and hence the same time available before touchdown the vertical beamspread will be increased pro rata, *ie*

$$B_{(x)} = B_{(3)}\left(\frac{x}{3}\right)$$

where $B_{(x)}$ = required beam spread for x° glideslope

$B_{(3)}$ = specified beamspread for 3° glideslope (ICAO)

x° = required glideslope

ie for 6° glideslope

Beamspread(6) = beamspread (3) × 6/3

Beamspread(6) = 2 × beamspread (3).

4 MAINTENANCE STANDARDS

High intensity airfield lighting is designed to support low visibility operations. It is only in the lowest visibilities (<800 metres RVR) that the full intensity is essential. Until recently, at most airfields the lighting has not been used in critical, maximum performance conditions since very few operations have taken place in RVR <800 metres. However, the situation is now changing very rapidly. Consequently there is a real concern that levels of maintenance that in the past have been adequate will now be found to be deficient to a degree that adversely effects both the safety and regularity of operations.

Monitoring of civil and military airfield lighting systems has clearly demonstrated that lighting maintenance standards must be radically improved. For example, Figs 5 and 6 show two runways equipped for Category 1 operations. The facility shown in Fig 5 has been in recent use for Category 1 operations without adverse comment, whereas Fig 6 is what should be achieved and which will be necessary for Category 2 and 3 operations. Airport managements must be encouraged to maintain equipment to levels close to the performance shown in the ICAO/national specifications. A major problem will emerge very quickly as low visibility capabilities are exploited unless attention is given to this problem now. Means must be provided to monitor the output performance of this important element of the all-weather landing system in the same way that ILS/MLS and autopilot performance is monitored in service.

5 VISUAL AIDS FOR HELICOPTERS

When the subject of visual aids for helicopters is discussed a phrase often heard is "the unique characteristics of the helicopter". The phrase is usually associated with an expression of the opinion that helicopter operators do not want to be constrained by standardisation and regulation in respect to operational procedures and in particular to the use of a single set of visual aids. The helicopter does have unique characteristics; it can decelerate to a hover, so that it approaches touchdown very slowly, but it has other 'unique' features such as a heavy pilot workload while handling power changes and control cross-coupling during the deceleration phase. The reality of the situation as far as helicopter all-weather operations are concerned is that the problems are a somewhat different set of problems from those encountered in fixed wing operations.

As far as visual aids are concerned many of the same principles of design apply. Visual aids are required for the final phases of the approach and landing unless the helicopter is being flown automatically.

In low visibility conditions, two main types of operation are emergine:

(a) An instrument approach to the hover.

(b) An instrument approach to the point where the deceleration phase begins.

Operations of the second type rely quite heavily on adequate visual cues in the approach, hover and landing areas, whereas the first type only require visual cues for the final hover and landing manoeuvres. For the second type of operation visual systems already developed for fixed wing operations will suffice and it is unlikely that anything substantially less than this will be sufficient. This conclusion has, of course, profound economic implications and requires a heliport of large dimensions.

Operations of the first type impose far fewer demands on the visual aids designer and installation engineer. In the long-term it is likely that this method of operation will become the dominant means of making low visibility approaches (RVR <400 metres) but in the interim operations are likely to rely quite heavily on visual aids.

Lighting aids on and adjacent to the touchdown and lift-off area cannot be of a high intensity because pilots will be dazzled. Hence any high intensity approach guidance must be located away from the landing area.

Generally, lighting equipment designed for fixed wing operations will be usable at heliports. There are two likely areas where technology advances will make an impact. The first is a high intensity strobe beacon flashing the morse letter H as a heliport identification (see Fig 7) and low intensity lighting panels to define the landing area. Flight trials have been carried out on both of these aids by members of the ICAO Visual Aids Panel Working Group on Helicopter Visual Aids.

The heliport beacon when seen in flight is a unique signal, easily distinguished in any environment and the panel lighting is strongly preferred to conventional omni-directional edge lighting because since it has known dimensions it provides a strong cue of distance at short range and a clear indication of the location of the landing surface.

Glideslope indications for helicopter operations are also the subject of international debate. ICAO is adopting the signal format shown in Fig 8. In the UK there is an equipment under evaluation that provides this signal omnidirectionally, but the usable range is only about 1 km. The signal colours chosen by ICAO were selected to coincide with the colour format used in PAPI, but there are good reasons for believing that this decision is wrong. If green is used instead of white then the problem of mis-identification of a false white signal generated by colour aberration or lens contamination is avoided. This problem does not exist to the same extent in a multi-unit array such as PAPI, but for example, in offshore situations where salt spray can contaminate the lens there is a real possibility of the colour of a single signal light being mis-interpreted. Further consideration and operating experience of the Helicopter Approach Path Indicator may well cause a change to the red/green format in due course.

6 SURFACE MOVEMENT, GUIDANCE AND CONTROL

This topic is one of the most active areas of concern at the present time. The tragic events in Tenerife, Madrid and Alaska and the mounting evidence of unauthorised runway incursion have alerted the aviation community to the need for positive action to be taken.

The simplest means of tackling the problem is to use appropriate visual aids to guide and control the surface movement of aircraft. This requires the development of a standardised set of signs and lights that define and protect a 'red line' that completely and continuously encompasses every active runway. The visual guidance must be applied both to aircraft and to vehicles. Every taxiway, crossing runway and roadway must be treated as a potential hazard.

A number of guiding principles are beginning to emerge:

(a) Standardisation is mandatory.

(b) Integrity of switching is essential for all lighting systems and illuminated signs used in SMGC.

(c) The quantity of visual aids should be kept to a minimum. A profusion of signs only dilutes the essential information.

In this latter context the selectably addressable sign is attractive since such a technique can result in only those signs that are relevant to operations at that time being displayed. Selectable signs can be of the simple, fixed message type or they could be of the variable message type used in other applications such as departure boards in terminals. Signs are clearly essential in many cases where RT messages can be mis-heard or misunderstood.

The specifications of SMGC aids should be related to visibility and not category of landing operation, since it is possible to taxi for take-off in visibilities well below the limits imposed for landing, *ie* an airfield may only be suitable for Category 1 landings (800 metres) but may be suitable for take-off in 200 metres. The 'red line' principle is illustrated in Fig 9 and some examples of possible signs are shown in Fig 10.

7 CONCLUSIONS

Airfield lighting requirements are constantly evolving as operational conditions change and new types of operation are developed. Visual aids will continue to play a vital role in ensuring the safety and regularity of aircraft operations both in the air and on the ground. Airfield lighting standards and practices must take account of new technology if future requirements are to be met adequately.

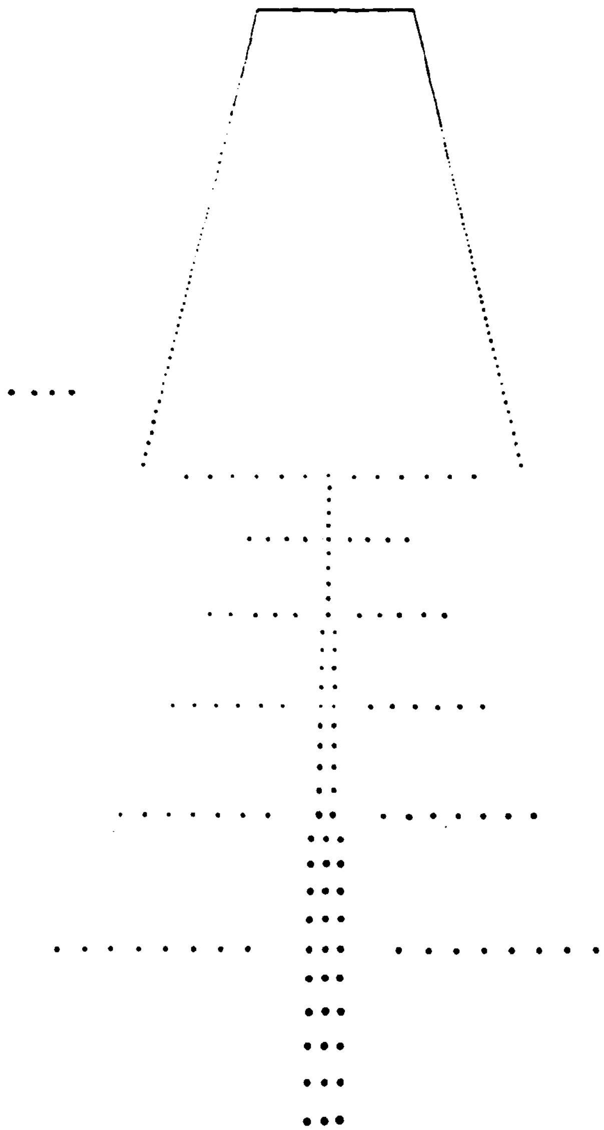


Fig 1 ICAO Cat i lighting

Fig 2

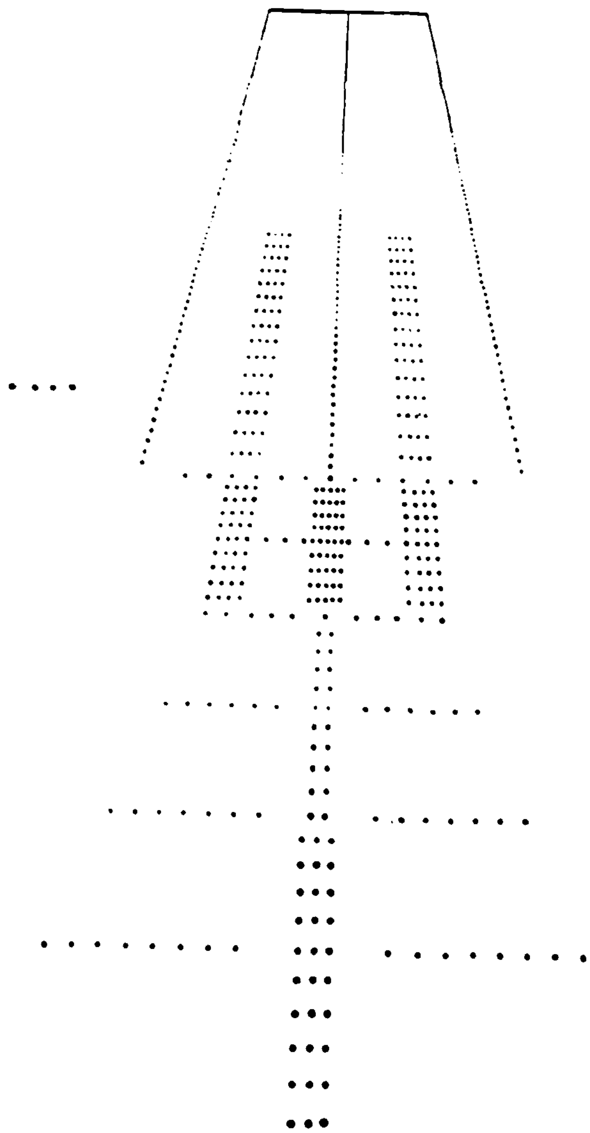
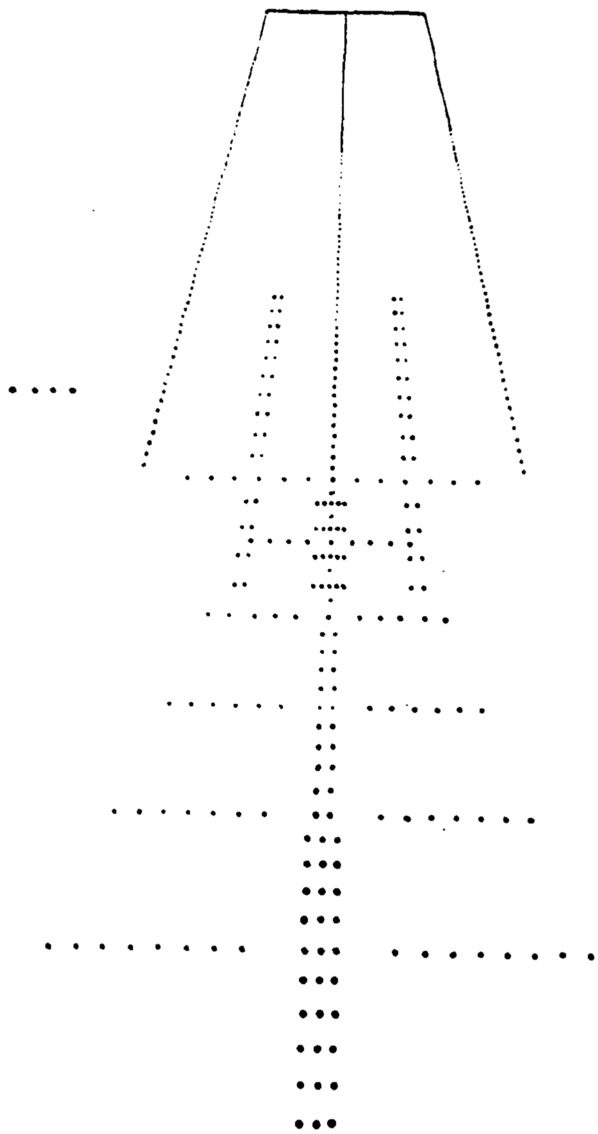


Fig 2 ICAO Cat 2/3 lighting

Fig 3



N.B.Runway centreline only required for RVR < 300m.

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Fig 3 Economic - Cat 2/3 lighting

Fig 4

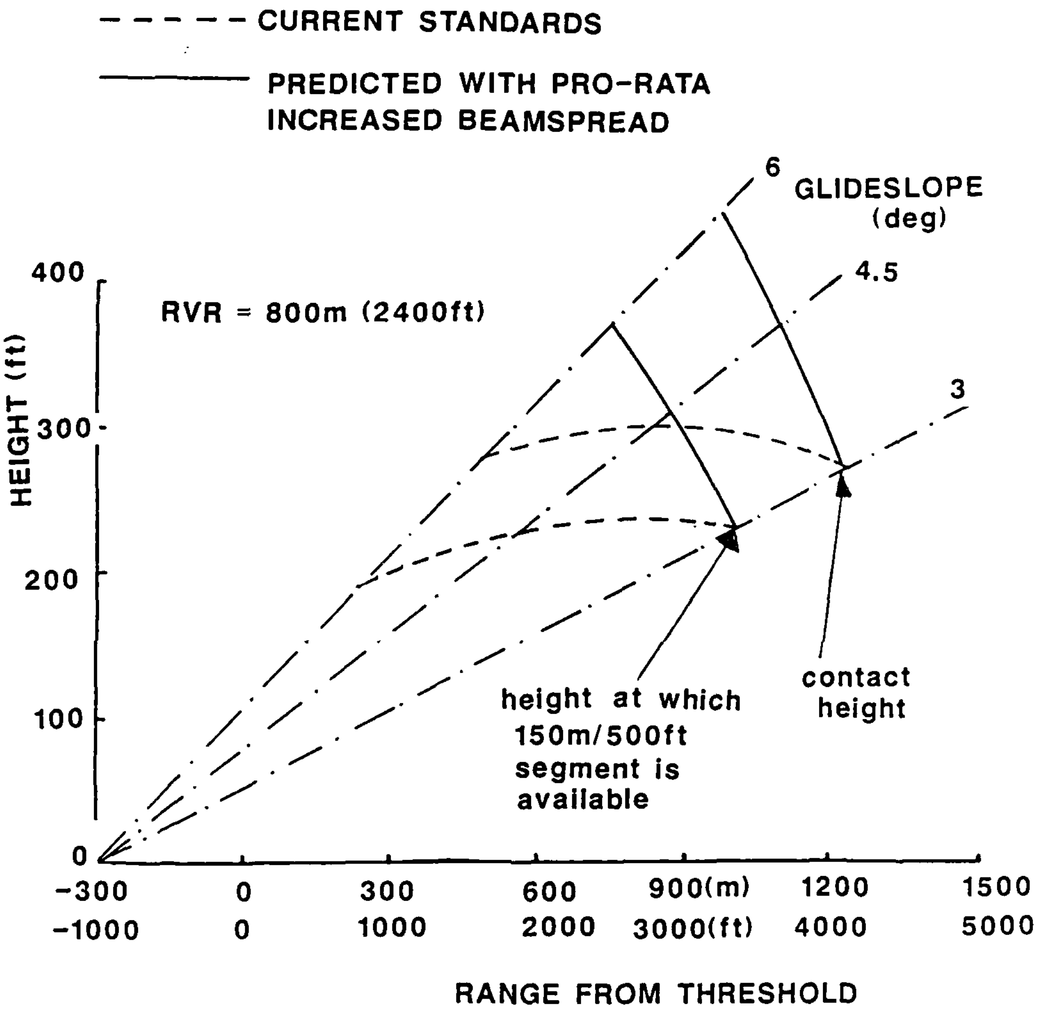


Fig 4 Range performance of airfield lighting for various glideslope angles

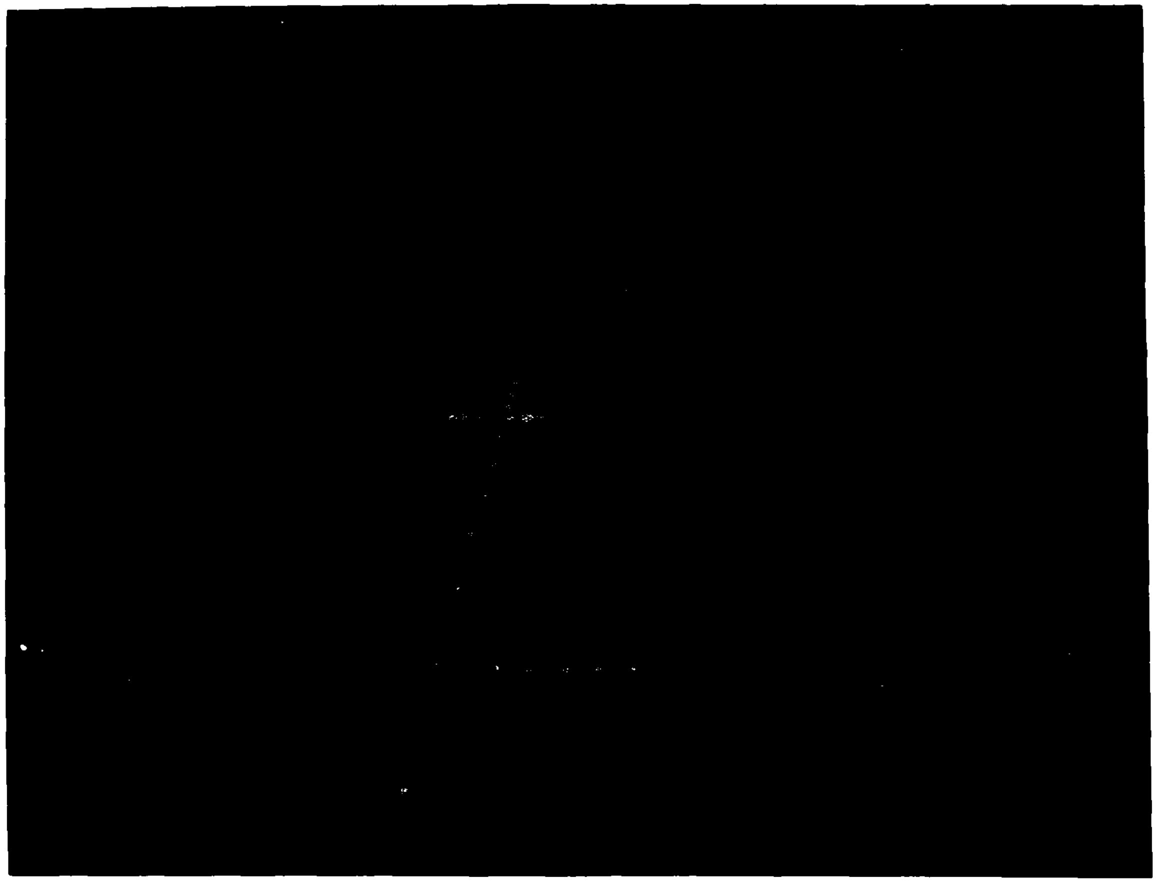


Fig 5 Sub-standard lighting performance

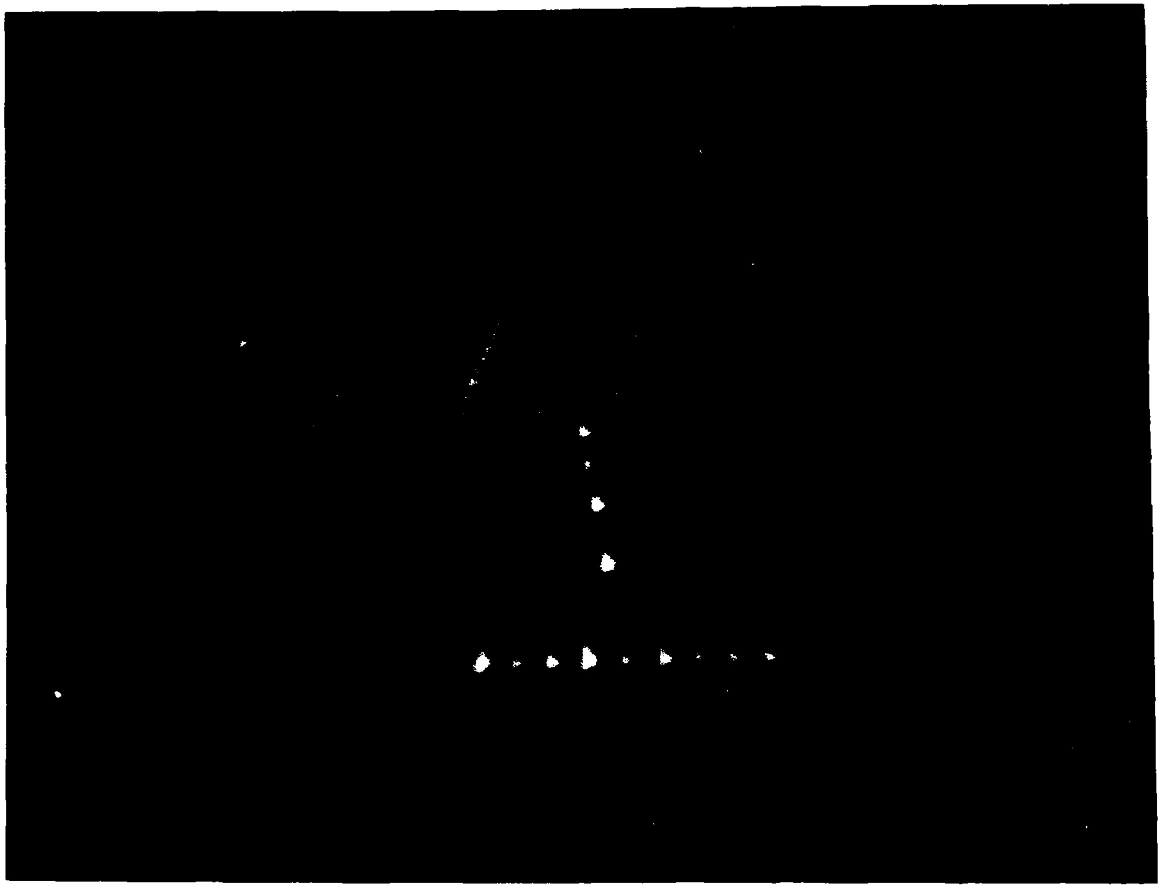
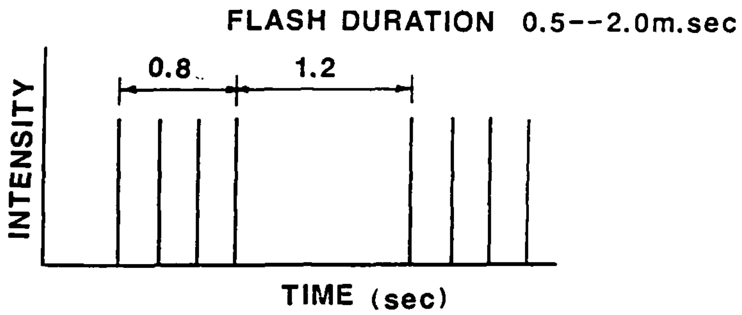


Fig 6 Standard lighting performance



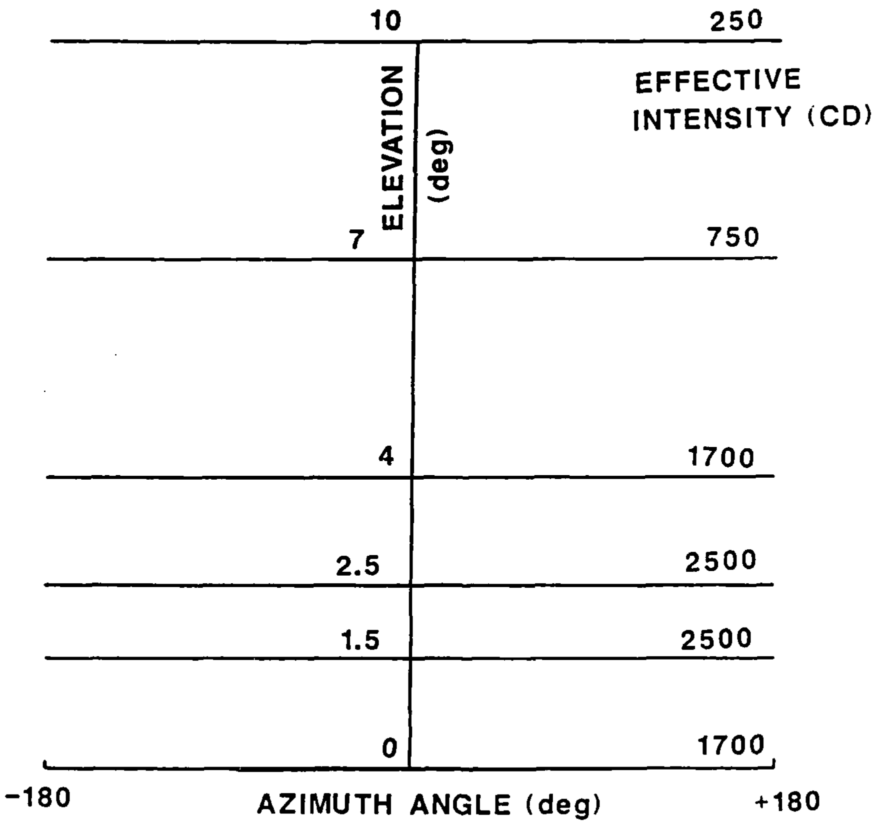
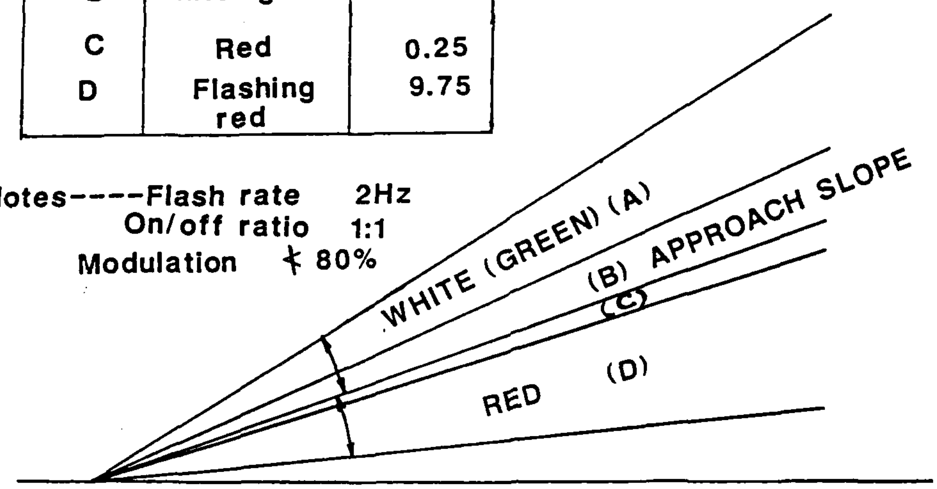


Fig 7 Heliport beacon characteristics

Fig 8

Sector	Format	Angular Size(deg)
A	Flashing white (green)	9.25
B	White (green)	0.75
C	Red	0.25
D	Flashing red	9.75

Notes----Flash rate 2Hz
On/off ratio 1:1
Modulation $\not<$ 80%



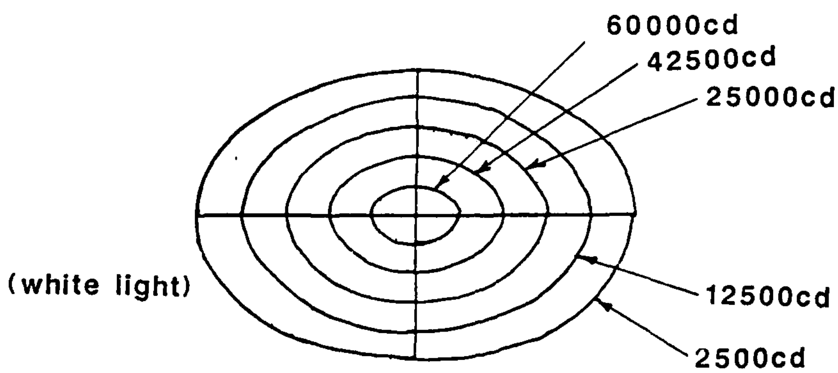
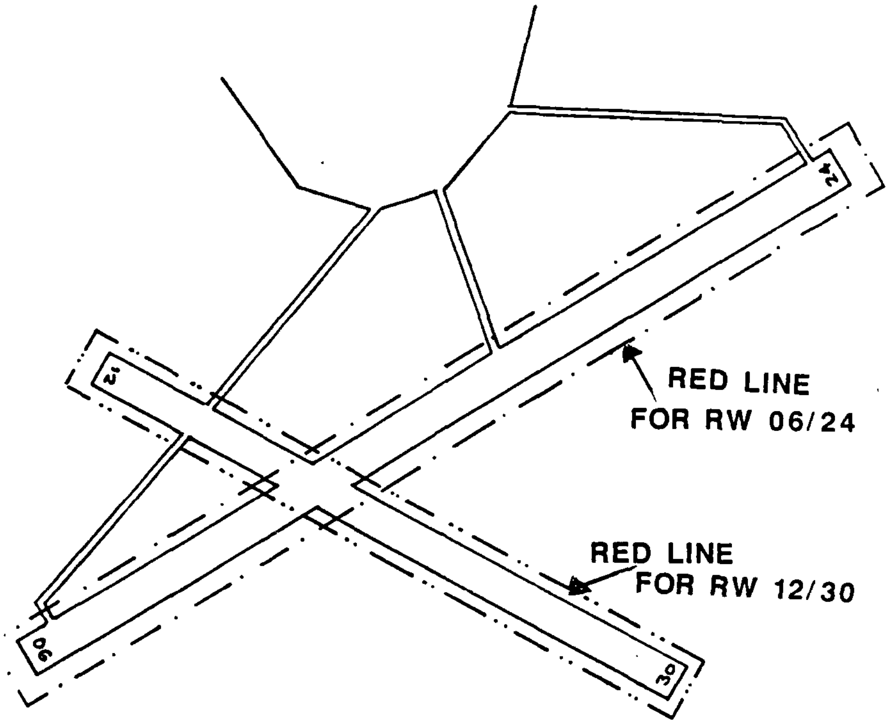


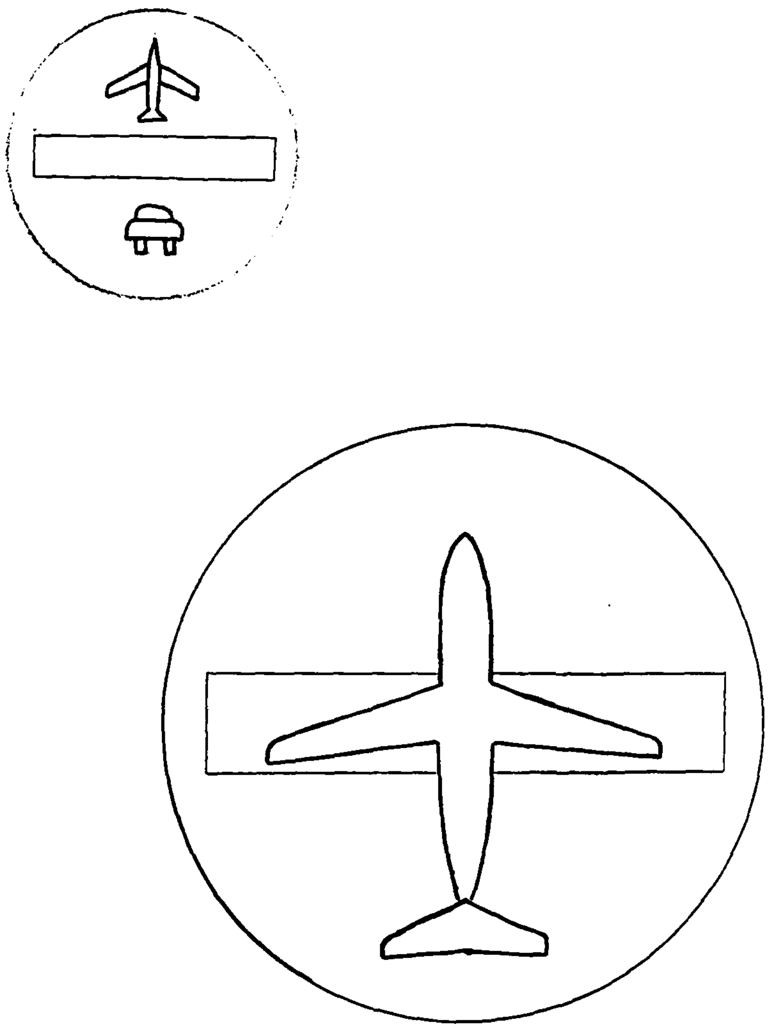
Fig 8 Helicopter approach path indicator characteristics



Note--A red signal (sign/light)must be installed at all locations where the red line crosses a runway access (aircraft/vehicle)

Fig 9 The 'Red line' principle

Fig 10



Suggested 'no entry' sign for use on manoeuvring areas at aerodromes. An alternative design would also include a vehicle symbol (see small diagram) to ensure that ground vehicles do not enter the prohibited area.

Fig 10 Possible 'no entry' sign for SMGC

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17\. Abstract

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The Memorandum also considers the evolving requirements for visual aids to support helicopter operations and to enhance surface movement, guidance and control.